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(54) Exposure apparatus and device manufacturing method using the same

(57) A scanning exposure apparatus wherein a portion of a pattern of an original is projected on to a substrate through a projection optical system (2) and wherein the original and the substrate are scanningly moved relatively to the projection optical system (2) whereby the pattern of the original is transferred on to the substrate. The apparatus includes an original stage (1) for holding the original, a base (9) for supporting the original stage (1), and a supporting system for supporting the base (9) at three positions, through dampers (11) and pillars (12).

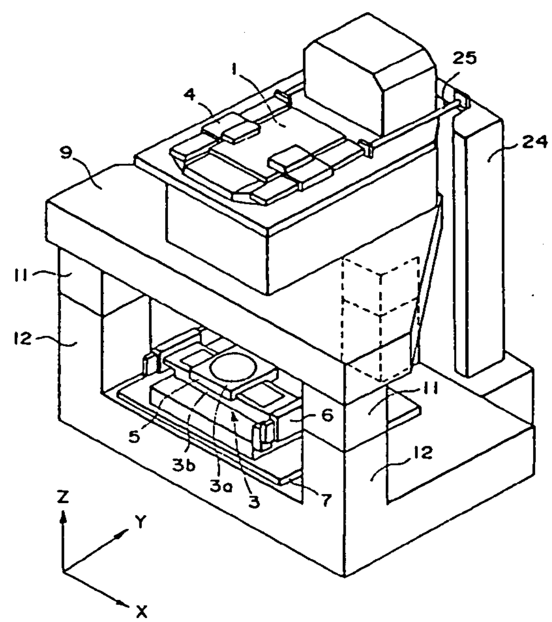

FIG. 2

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Description

This invention relates to an exposure apparatus for use in manufacture of semiconductor devices, for example, for lithographically printing a design pattern on a substrate. In another aspect, the invention is concerned with a device manufacturing method which uses an exposure apparatus such as above.

As for such exposure apparatus, there are a projection exposure apparatus (stepper) for printing a pattern of an original on to different exposure areas on a substrate such as a wafer, sequentially through a projection optical system while moving the substrate stepwise, and a scanning exposure apparatus for printing a pattern of an original such as a mask on to a substrate while synchronously moving the original and the substrate relatively to a projection optical system.

Further, a step-and-scan type exposure apparatus has been recently proposed for higher precision printing of fine pattern, as disclosed in U.S. Patent Nos. 5,473,410, 5,477,304 and 5,491,534, for example. In such exposure apparatus, stepwise motion and scanning exposure as mentioned above are repeated, to perform high precision printing on to plural regions on a substrate. Since in this type of exposure apparatus, with restriction by a slit, only a portion relatively near an optical axis of a projection optical system is used, higher precision and wider frame size printing of fine pattern is enabled.

However, in such step-and-scan type exposure apparatus or in any other exposure apparatus for which high precision printing is required, positional alignment between an original and a substrate should be improved to completely utilize the performance of a projection optical system and to increase the exposure precision significantly.

An aspect of the present invention can provide a novel technique for use in exposure apparatus or in device manufacture, for improving positional alignment between an original and a substrate.

More specifically, an aspect of the present invention can modify the relation between support for a projection optical system, an original or a substrate, for example, and a scan direction of the substrate, and avoid or reduce unwanted deformation of support means resulting from movement of a substrate stage during scan exposure.

A second aspect of the present invention can avoid or reduce deterioration of precision for measurement of positional interrelation among a projection optical system, an original and a substrate, attributable to deformation of such support means, to thereby assure high precision control of the positional interrelation.

A third aspect of the present invention can reduce heat generation resulting from movement of a substrate stage, to assure temperature stabilization and to thereby avoid or reduce degradation of exposure precision due to non-uniform temperature or variation in temperature.

A fourth aspect of the present invention invention can assure high precision movement of a substrate in a scan direction during scanning exposure process, with a simple structure.

Embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a schematic and sectional side view of an exposure apparatus according to an embodiment of the present invention.

Figure 2 is a perspective view of the exposure apparatus of Figure 1.

Figure 3 is a schematic view for explaining positional relationship of a damper (support pillar) of the apparatus of Figure 1, a scan direction for scanning exposure, a projection exposure apparatus, and exposure light used, as viewed from the above.

Figure 4 is a graph for explaining changes with time of movement speeds of an X stage and of a Y stage, of the apparatus of Figure 1, during stepwise motion and scan exposure.

Figure 5 is a schematic view for explaining positional relationship of a support point for a stage base of the apparatus of Figure 1 and a measurement point for the stage base.

Figure 6 is a flow chart for explaining sequence of microdevice manufacturing processes.

Figure 7 is a flow chart for explaining details of a wafer process included in the sequence of Figure 6.

Preferred embodiments of the present invention will be described with reference to the drawings. Figure 1 is a schematic and sectional side view of an exposure apparatus according to an embodiment of the present invention. Figure 2 is a perspective view of the outside appearance of the exposure apparatus. As shown in these drawings, in this embodiment, the invention is applied to a step-and-scan type exposure apparatus wherein a portion of a pattern of an original, placed on a reticle stage 1, is projected on to a wafer, placed on an X-Y stage 3, through a projection optical system 2. The reticle and the wafer are moved (scanned) synchronously in Y direction relatively to the projection optical system 2, whereby the pattern of the reticle (original) is transferred to the wafer (substrate to be exposed). Such scanning exposure is repeatedly effected to different areas on the wafer and, to this end, stepwise motion is performed together with the scan exposure.

The reticle stage can be moved in Y direction by means of a linear motor 4. An X stage 3a of the X-Y stage 3 can be moved in X direction by means of a linear motor 5, while a Y stage 3b can be moved in Y direction by means of a linear motor 6. For synchronous scan of the reticle and the wafer, the reticle stage 1 and the Y stage 3b are moved in Y direction at a constant speed ratio (e.g., 4:1). Also, the stepwise motion in X direction is performed by using the X stage 3a.

The X-Y stage 3 is disposed on a stage base 7, and

the stage base 7 is supported on a base table 10 at three positions, through three dampers 8. The reticle stage 1 and the projection optical system 2 are mounted on a barrel base 9 which is supported on the base table at three positions, through supporting means that comprises pairs of dampers 11 and pillars 12. Each damper 8 comprises an active damper which functions to actively suppress or isolate vibration in six axis directions. However, a passive damper may be used in place thereof or, alternatively, the support may be provided without use of damper.

Figure 3 is a schematic view for explaining positional interrelation of dampers 11 (or pillars 12), scan direction during scanning exposure, projection optical system 2, and exposure light, as viewed from the above. As shown in this drawing, the three support points for the barrel base 9 provided by the dampers 11 and pillars 12, define an approximately isosceles triangle. The scan direction Y is parallel to a straight line 17 which connects the gravity center 18 of the triangle and the intersection point between the isosceles sides of the triangle. Also, the gravity center 18 is substantially aligned with the gravity center 19 of the projection optical system 2. Denoted at 20 in the drawing denotes section of exposure light which is formed with a slit-like shape. The lengthwise direction of the slit shape corresponds to a direction (X direction) perpendicular to the scan direction. Two of the three dampers 11 are placed in a front portion of the apparatus, while the remaining one is placed in a rear portion of the apparatus. Path for introduction of wafer into the apparatus is defined, from the front portion of the apparatus and between the two pillars 12 disposed in the front portion of the apparatus.

The exposure apparatus further includes distance measuring means 13 such as a laser interferometer or a micro-encoder, for example, for measuring the distance between the barrel base 9 and the stage base 7 in Z direction, at three points. As shown in Figure 5, the three measurement points P upon the stage base 7 are, with respect to the measurement direction, on the elongations of three sides of a triangle as defined by the three support points provided by the dampers 8.

Alternatively, distance measurement may be performed while taking into account the magnitude of deformation, at these measurement points, of the stage base resulting from movement of the X-Y stage 3 which can be measured beforehand.

Further, as shown in Figures 1 and 2, the exposure apparatus is further equipped with a reactive force receiving mechanism 24 for receiving reaction force caused in the scan direction as a result of scan movement (acceleration or deceleration) of the reticle stage 1, as well as a connecting member 25. The reactive force receiving mechanism 24 is supported by the base table, independently from the barrel base 9.

With the structure described above, a waver is conveyed and fed on to the X-Y stage 3 by conveying means (not shown), along a conveying path defined between the two pillars 12 in the front portion of the apparatus. After predetermined alignment procedure is completed, in the exposure apparatus, scanning exposure and stepwise motion are repeated, and a pattern of the reticle is lithographically transferred on to different exposure areas on the wafer. During scan exposure, the reticle stage 1 and the Y stage 3b are moved in Y direction (scan direction) at a predetermined speed ratio, whereby the pattern of the reticle is scanned with slit-like exposure light. Also, the wafer is scanned with a projected image of it, whereby the pattern of the reticle is printed on a predetermined exposure area on the wafer. After scan exposure of one exposure area is completed, the X stage 3a is moved in X direction (wafer stepwise motion), whereby another exposure area is positioned with respect to the scan exposure start position. Scan exposure of that exposure area is then performed. In order that sequential exposures of plural exposure areas of the wafer are performed efficiently through the combination of stepwise motion in X direction and scan exposure movement in Y direction, preferably placement of exposure areas, scan direction (positive or negative in Y), and order of exposures of the exposure areas, for example, are predetermined.

As the reticle stage 1 moves during the scan exposure operation, the gravity center thereof shifts and, thus, tilt or state of deformation of the barrel base 9 changes. However, as described, the supporting points for the barrel base 9 define an isosceles triangle, and the scan direction Y is parallel to the straight line 17. Additionally, the gravity center of the isosceles triangle coincides with the gravity center of the projection optical system 2. Therefore, the gravity center of the reticle stage 1 passes substantially along the straight line 17. As a result, tilt of the barrel base 9 resulting from the movement of the reticle stage 1 comprises a component in Y (Z) direction only. It does not incline in X direction. Further, the quantity of deformation of the barrel base 9 is symmetric with respect to the straight line 17. Thus, since, even with such deformation, the slit shape of the exposure light is still perpendicular to the scan direction, adverse effect of any tilt in Y direction can be removed simply by adjusting the wafer position in Z direction. If on the other hand the barrel base 9 is inclined in X direction, since the slit shape 20 is elongated in X direction it is very difficult to remove the effect of such tilt.

Further, since the barrel base is supported at three points, positional interrelation of the position of the reticle stage 1, the amount of deformation of the barrel base at respective points, and the positions of the support points is determined definitely. Therefore, as compared with a four-point support system, better reproducibility is assured in regard to deformation. Thus, where deformation of barrel base 9 due to movement of the reticle stage 1 should be taken into account or should be corrected, it can be done with high precision. For example, as shown in Figure 1, whether or not the wafer is placed at the focus position of the projection optical

system 2 can be discriminated by projecting light to the wafer in an oblique direction, from light projecting means 21 fixed to the barrel base 9 and by detecting the position of reflected light therefrom through light receiving means 22. In such case, accurate focus position detection can be done while taking into account the exact amount of deformation of the barrel base 9. Further, as r gards the measurement with the laser interferometer 23 for detection of wafer position in X, Y and θ directions, it may be performed precisely while taking into account the deformation amount of the barrel base 9.

Further, during scan exposure or stepwise motion, the barrel base 9 or the stage base may tilt as a result of movement of the reticle stage 1 or of the X-Y stage 3. If this occurs, it is necessary to correct the same. To this end, by using the distance measuring means 13, the distance between the barrel stage 9 and the stage base 7 may be measured, in the vicinity of their three support points. Here, the measurement points upon the stage base 7 are, with respect to its measurement direction, on straight lines each passing through a tip of triangle, defined by the three support points, and a middle point of side adjacent to that tip. At theses measurement points, the amount of deformation of the reticle stage 1 or of the X-Y stage 3 is so small that it can be disregarded, measurement may be performed without taking into account the amount of deformation.

If on the other hand the deformation of an amount that can not be disregarded, such deformation may be measured beforehand in connection with the position of the reticle stage 1 or X-Y stage 3. Then, exact distance between the barrel base 9 and the stage base 7 can be measured precisely, while taking into account the amount of such deformation. In that occasion, because of three-point support as described, reproducibility of deformation is good and, thus, the amount of deformation can be reflected precisely.

Figure 4 ((a) and (b)) is a graph for explaining an example of changes with time of movement speeds of X stage 3a and Y stage 3b during stepwise motion and scanning exposure. As the acceleration of Y stage starts, after elapse of an acceleration period of 0.051 sec. and a regulation period of 0/05 sec., the Y stage moves at a constant speed 100 mm/sec for a period of 0.375 sec. In this constant-speed movement period, the exposure process is performed. After this exposure period, the Y stage is decelerated and, additionally, acceleration of the X stage is initiated to perform stepwise motion. After the stepwise motion is completed, acceleration of the Y stage is initiated again in a similar way. In this manner, motion of the X and Y stages is repeated, such that the pattern of the reticle is printed on to different areas on the wafer sequentially through scan exposures.

It is now assumed that the X stage has a weight of 30 Kg, and the Y stage has a weight of 60 Kg, and that acceleration and deceleration such as shown in Figure 4 are to be performed. If in that case the conditions are such that largest acceleration of the X and Y stages is 0.2 G; highest scan speed is 100 mm/sec.; highest stepwise motion speed is 350 mm/sec.; r gulation p riod is 0.15 sec.; exposure view angle (size of exposure range for ach exposure area) is 32.5x25(mm); scan distance is 37.5 (32.5+5) mm; thrust constant of linear motor for moving the X and Y stage is 20 N/A; then duties Dy and Dx at acceleration and deceleration during scan motion and stepwise motion are as follows:

$$Dy = 0.051 \times 2/1.006 = 0.101$$

$$Dx = 0.179 \times 2/1.006 = 0.356$$

The quantities Q1y and Q1x of heat generation of the Y stage and X stage are:

$$Q1y = \{(60 \times 9.8 \times 0.2)/(20 \times 2)\}^2 \times 5 \times 2 \times 0.101 = 8.73\ [w]$$

$$Q1x = \{(30 \times 9.8 \times 0.2)/20\}^2 \times 5 \times 0.35 = 15.39\ [w]$$

The sum of generated heat quantities is 24.12 [w]. If on the other hand the X stage is moved in the scan direction and the stepwise motion is provided by the Y stage (the remaining portion is similar to that described above), the quantities Q2y and Q2x of the X and Y stages in that occasion are:

$$Q2x = \{(30 \times 9.8 \times 0.2)/20\}^2 \times 5 \times 0.101 = 4.37\ [w]$$

$$Q2y = \{(60 \times 9.98 \times 0.2)/(20 \times 2)\}^2 \times 5 \times 2 \times 0.356 = 30.77\ [w]$$

The sum of generated heat quantities is 35.14 [w]. Thus, by using the lower Y stage of heavier weight for the scan motion of smaller duty, it is possible to reduce the quantity of heat generation. Also, as described, by setting the movement direction of the upper X stage of lighter weight in a direction perpendicular to the scan direction and by performing correction of drive error of the reticle stage 1 in the component perpendicular to the scan direction (or by performing offset adjustment movement therefor) while using that X stage, the precision of correction or the like can be enhanced significantly. Therefore, it is a possible alternative to provide the reticle stage 1 only with one-direction driving means for movement in scan direction only.

In this embodiment, as has been described above, a projection optical system and a stage for original are disposed on bases which are supported through dampers and pillars at three points. Also, a gravity center of

a triangle defined by these three points and a gravity center of the projection optical system are made in alignment with each other. This assures good reproducibility of deformation of base attributable to movement of the original stage, such that it is possible to avoid the effect of deformation precisely. Moreover, since the original stage is moved, on the base, in parallel to a straight line that connects the gravity center and the point of intersection of isosceles sides of the triangle, any tilt or deformation of the base is prevented from adversely and largely affecting the slit direction of slit-like exposure light. Such tilt or deformation will be produced mainly in a direction perpendicular to the slit direction. Thus, it is easy to avoid the effect of that. Two of the three points of the triangle may be placed in the front portion of the apparatus while the remaining one point may be placed in the rear portion of the apparatus, such that conveyance of a substrate into the apparatus may be performed by passing it between the two support pillars placed at the two points in the front portion. This easily assures path of substrate conveyance and enables effective utilization of space.

Further, a substrate stage is provided, and measurement points for the position of three-point supported base or for the distance thereto are placed on straight lines each passing a tip of the triangle, defined by these three points, and a middle-point of side juxtaposed thereto. This enables measurement based on measurement points where only small deformation of base occurs due to movement of the substrate stage. Thus, high precision measurement is assured. Alternatively, such measurement may be performed while taking into account the amount of deformation of the base resulting from movement of the substrate stage, having being measured beforehand. Also this is effective to assure high precision measurement.

Further, since a second stage for moving a substrate in a direction perpendicular to the scan direction, for stepwise motion, is mounted on a first stage for moving the substrate in the scan direction for synchronous scanning, the amount of heat generation due to the movement of the substrate stage is reduced. Thus, temperature stabilization is ensured and, therefore, degradation of exposure precision resulting from non-uniform temperature or temperature variation can be avoided. Additionally, since correction in a direction perpendicular to the scan direction can be made by means of the second stage, the original stage can be provided by a simple structure with driving means for one axial direction only.

Next, an embodiment of device manufacturing method which uses an exposure apparatus such as described above, will be explained.

Figure 6 is a flow chart of procedure for manufacture of microdevices such as semiconductor chips (e.g. ICs or LSIs), liquid crystal panels, CCDs, thin film magnetic heads or micro-machines, for example. Step 1 is a design process for designing a circuit of a semiconductor device. Step 2 is a process for making a mask on the basis of the circuit pattern design. Step 3 is a process for preparing a wafer by using a material such as silicon. Step 4 is a wafer process which is called a pre-process wherein, by using the so prepared mask and wafer, circuits are practically formed on the wafer through lithography. Step 5 subsequent to this is an assembling step which is called a post-process wherein the wafer having been processed by step 4 is formed into semiconductor chips. This step includes assembling (dicing and bonding) process and packaging (chip sealing) process. Step 6 is an inspection step wherein operation check, durability check and so on for the semiconductor devices provided by step 5, are carried out. With these processes, semiconductor devices are completed and they are shipped (step 7).

Figure 7 is a flow chart showing details of the wafer process. Step 11 is an oxidation process for oxidizing the surface of a wafer. Step 12 is a CVD process for forming an insulating film on the wafer surface. Step 13 is an electrode forming process for forming electrodes upon the wafer by vapor deposition. Step 14 is an ion implanting process for implanting ions to the wafer. Step 15 is a resist process for applying a resist (photosensitive material) to the wafer. Step 16 is an exposure process for printing, by exposure, the circuit pattern of the mask on the wafer through the exposure apparatus described above. Step 17 is a developing process for developing the exposed wafer. Step 18 is an etching process for removing portions other than the developed resist image. Step 19 is a resist separation process for separating the resist material remaining on the wafer after being subjected to the etching process. By repeating these processes, circuit patterns are superposedly formed on the wafer.

While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the the scope of the following claims.

Claims

1. A scanning exposure apparatus wherein a portion of a pattern of an original is projected on to a substrate through a projection optical system and wherein the original and the substrate are scanningly moved relatively to the projection optical system whereby the pattern of the original is transferred on to the substrate, said apparatus comprising:

   an original stage for holding the original;
   a base for supporting said original stage; and
   supporting means for supporting said base at three positions, through damper means and pillar means.

2. An apparatus according to Claim 1, wherein said base supports said projection optical system as well as said original stage.

3. An apparatus according to Claim 1, wherein the three positions define an approximately isosceles triangle, and wherein the scan direction is parallel to a straight line that connects the point of intersection of isosceles sides of the triangle and a gravity center thereof.

4. An apparatus according to Claim 1, wherein the three positions define a triangle, and wherein a gravity center of the triangle is substantially aligned with a gravity center of said projection optical system.

5. An apparatus according to Claim 1, wherein two of the three positions are placed in a front portion of said apparatus and the remaining one position is placed in a rear portion of said apparatus, and wherein a path of conveyance of the substrate into said apparatus is set to extend between two pillar members of said pillar means, disposed at the two positions in the front portion of said apparatus.

6. An apparatus according to Claim 1, further comprising a reactive force receiving mechanism, supported separately from said base, for receiving a reaction force resulting from scan movement of said original stage.

7. An apparatus according to Claim 1, further comprising a substrate stage for holding and moving the substrate, a second base different from said first-mentioned base, for supporting said substrate stage, damper means for supporting said second base at three points, and measuring means for measuring positional relationship between said second base and the first-mentioned base.

8. An apparatus according to Claim 7, wherein said measuring means measures a distance between said second base and the firs-mentioned base, at three measurement points.

9. An apparatus according to Claim 8, wherein each of the three measurement point of said measuring means, upon said second base, is on a straight line corresponding to elongation of an associated side of a triangle defined by the three points.

10. An apparatus according to Claim 8, wherein the measurement through said measuring means is performed while taking into account the amount of deformation, at a measurement point on said second base, of said second base resulting from movement of said substrate stage, having been measured beforehand.

11. An apparatus according to Claim 1, further comprising a first stage for moving the substrate in a scan direction for scan of the substrate, and a second stage for moving the substrate in a direction perpendicular to the scan direction, for stepwise motion thereof, wherein said second stage holds the substrate and is mounted on said first stage.

12. A device manufacturing method including a process for transferring a pattern of an original on to a substrate by use of an exposure apparatus as recited in any one of claims 1 to 11.

13. Exposure apparatus comprising means for holding an original having a pattern to be transferred by the projection of radiation therethrough to a substrate, and supporting means for supporting the holding means at three positions using damping means.

14. Exposure apparatus according to claim 13 wherein said supporting means is arranged to support the holding means at three positions arranged in an equilateral triangle.

15. Exposure apparatus according to claim 14 wherein said holding means is arranged to hold the original at a position along a line passing through a corner and the centre of the equilateral triangle.

16. A method of manufacturing a semiconductor device comprising the steps of:

    placing a substrate in the exposure apparatus of any one of claims 1 to 11 or 13 to 15;
    exposing the substrate to a pattern of the original; and
    fabricating a semiconductor device using the exposed substrate.

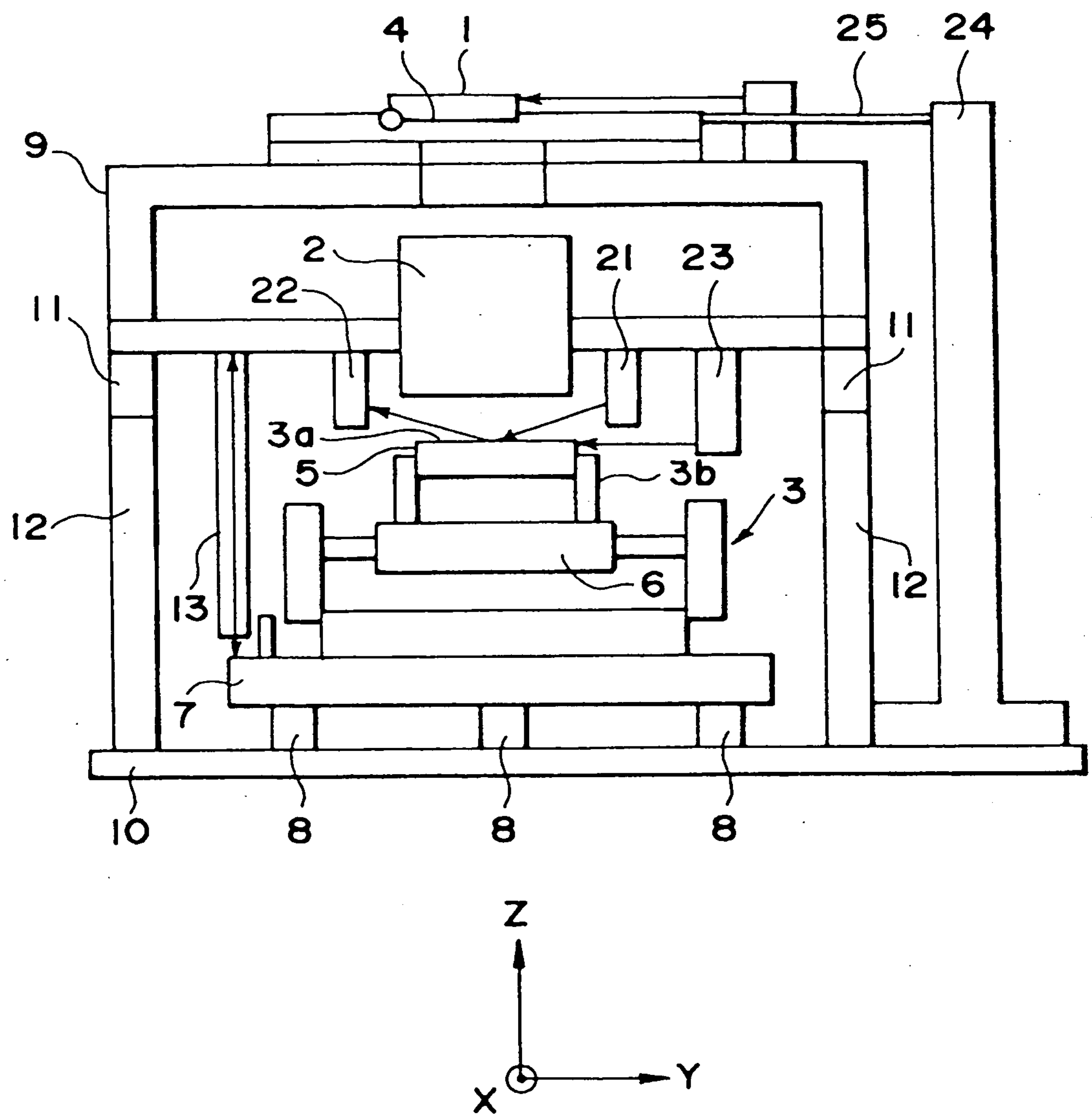


FIG. 1

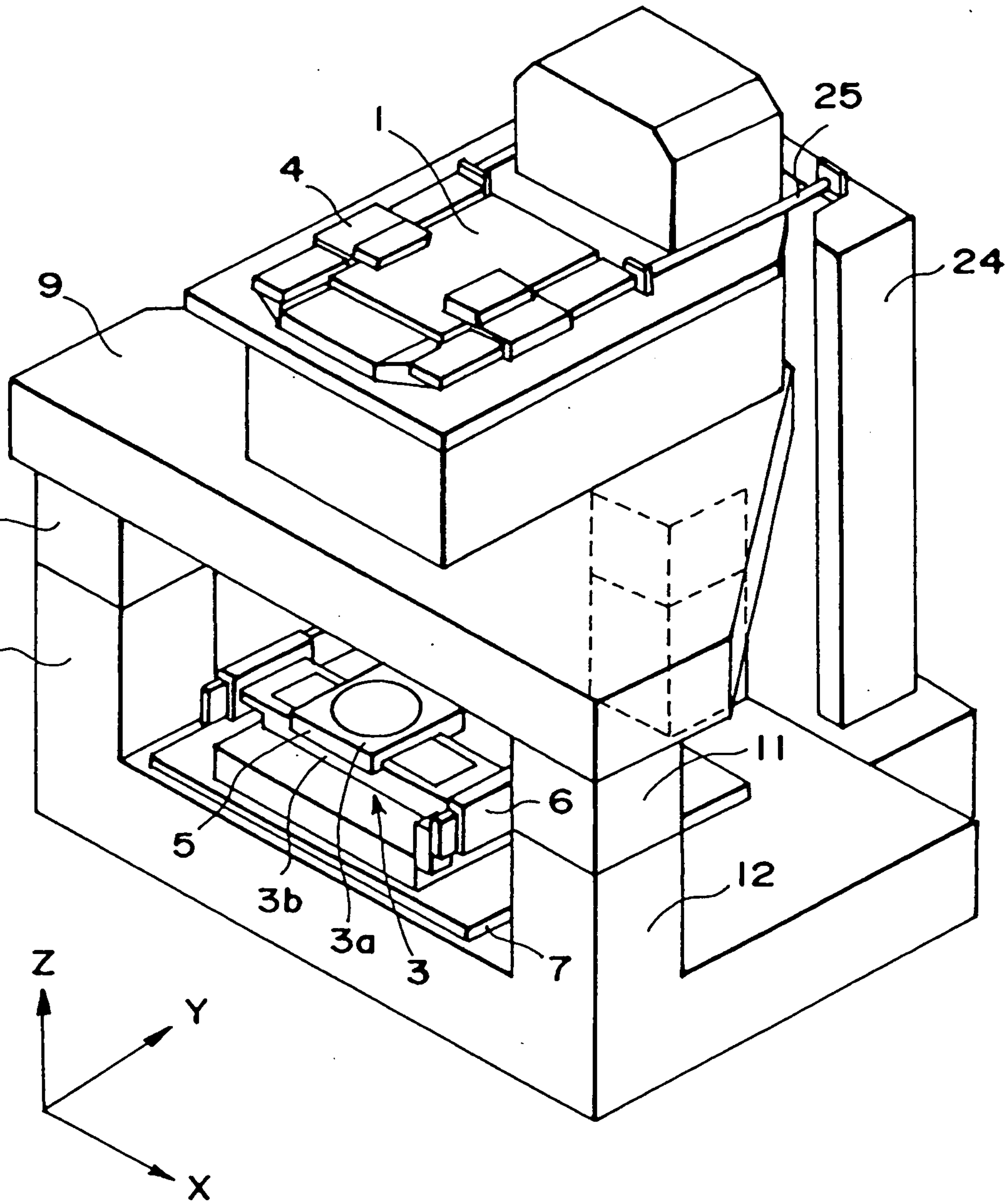


FIG. 2

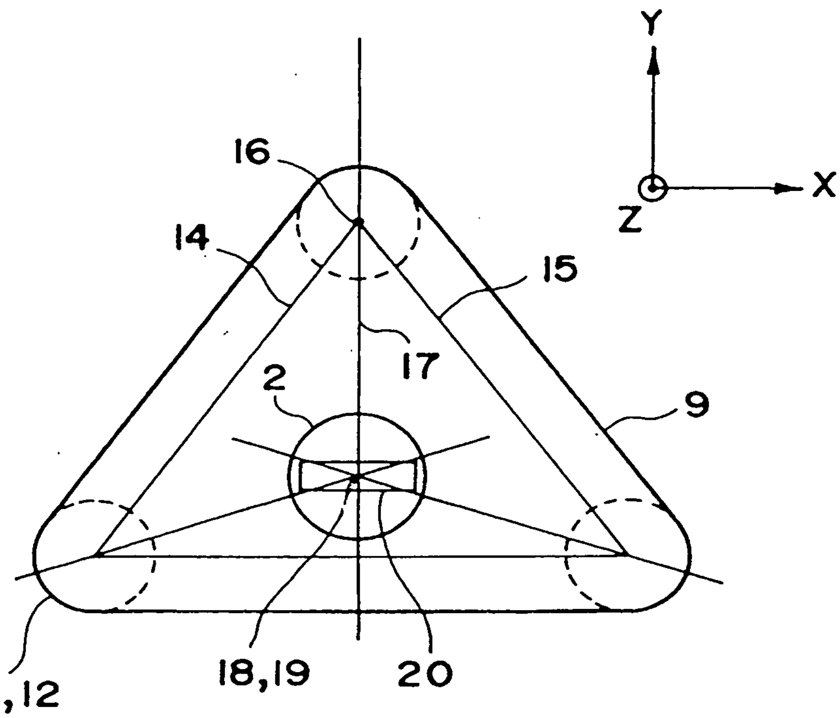
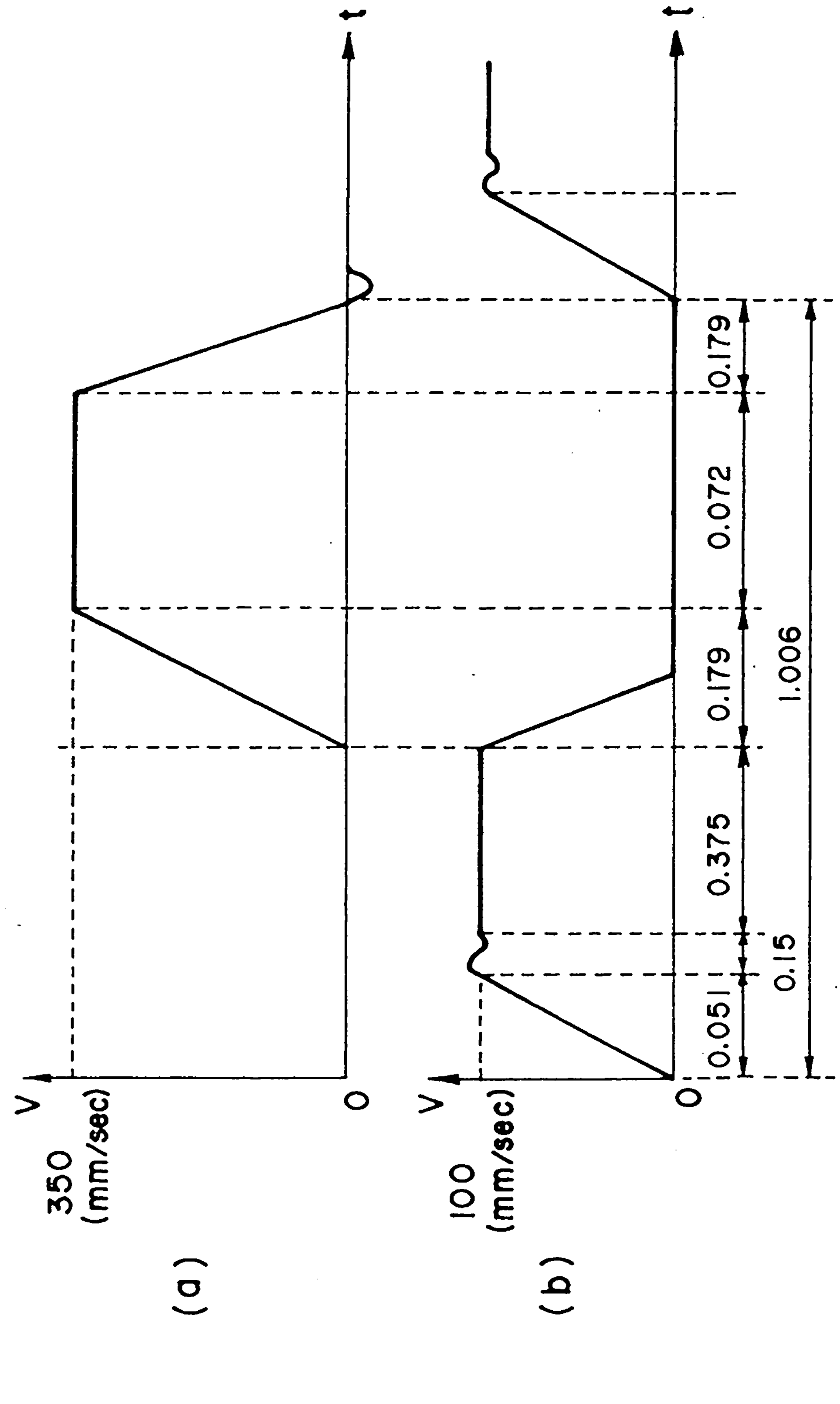


FIG. 3


(a)
350 (mm/sec)
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t
(b)
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0.051
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0.375
0.179
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FIG. 4

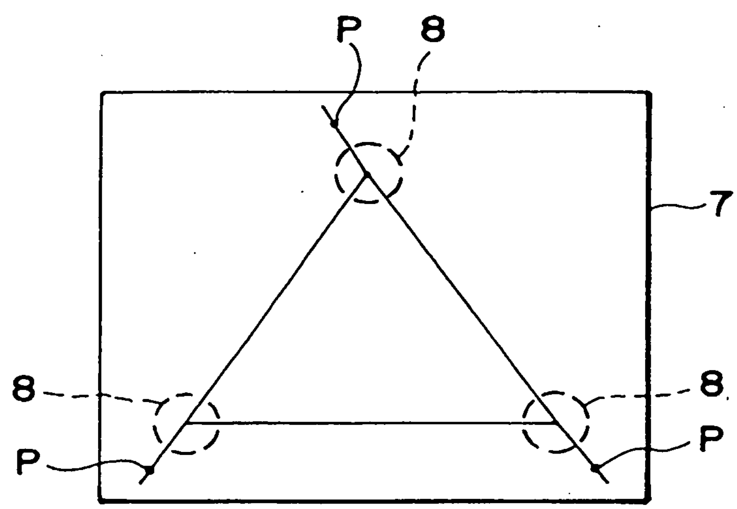
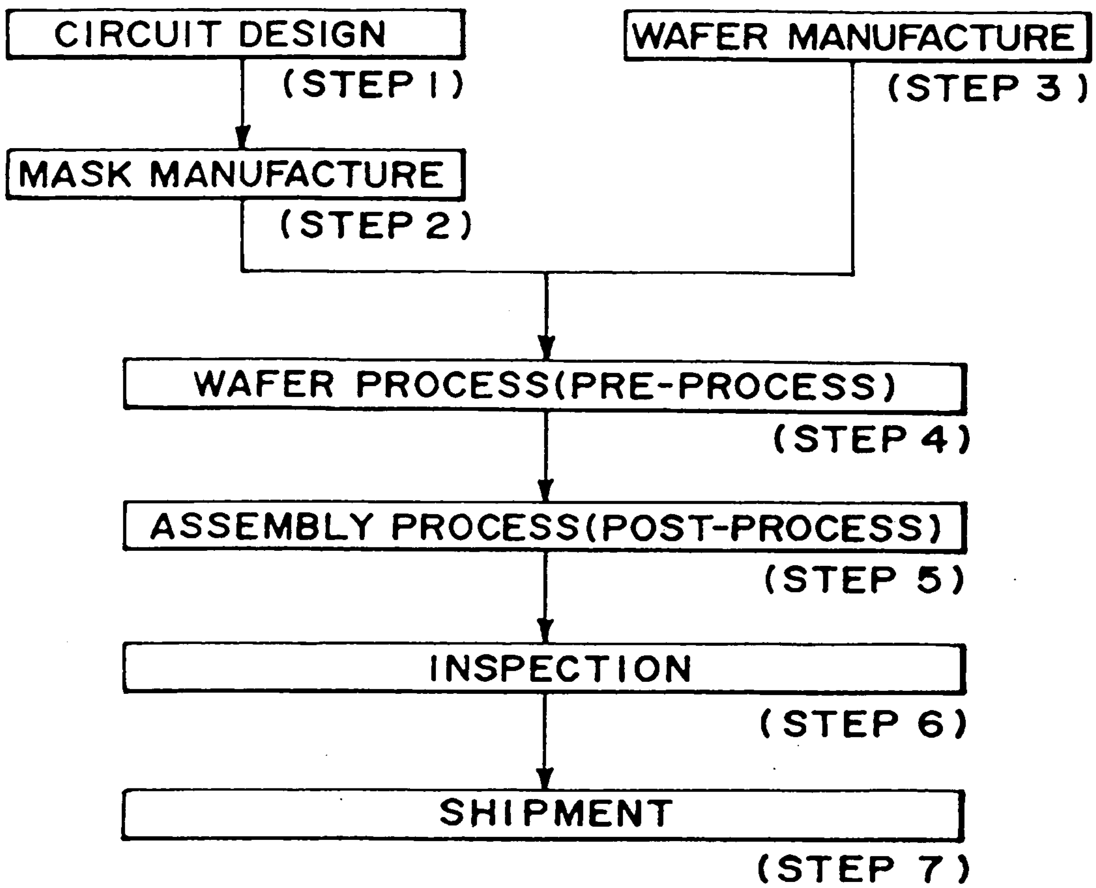


FIG. 5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(STEP 1)
WAFER MANUFACTURE
(STEP 3)
MASK MANUFACTURE
(STEP 2)
WAFER PROCESS(PRE-PROCESS)
(STEP 4)
ASSEMBLY PROCESS(POST-PROCESS)
(STEP 5)
INSPECTION
(STEP 6)
SHIPMENT
(STEP 7)

FIG. 6

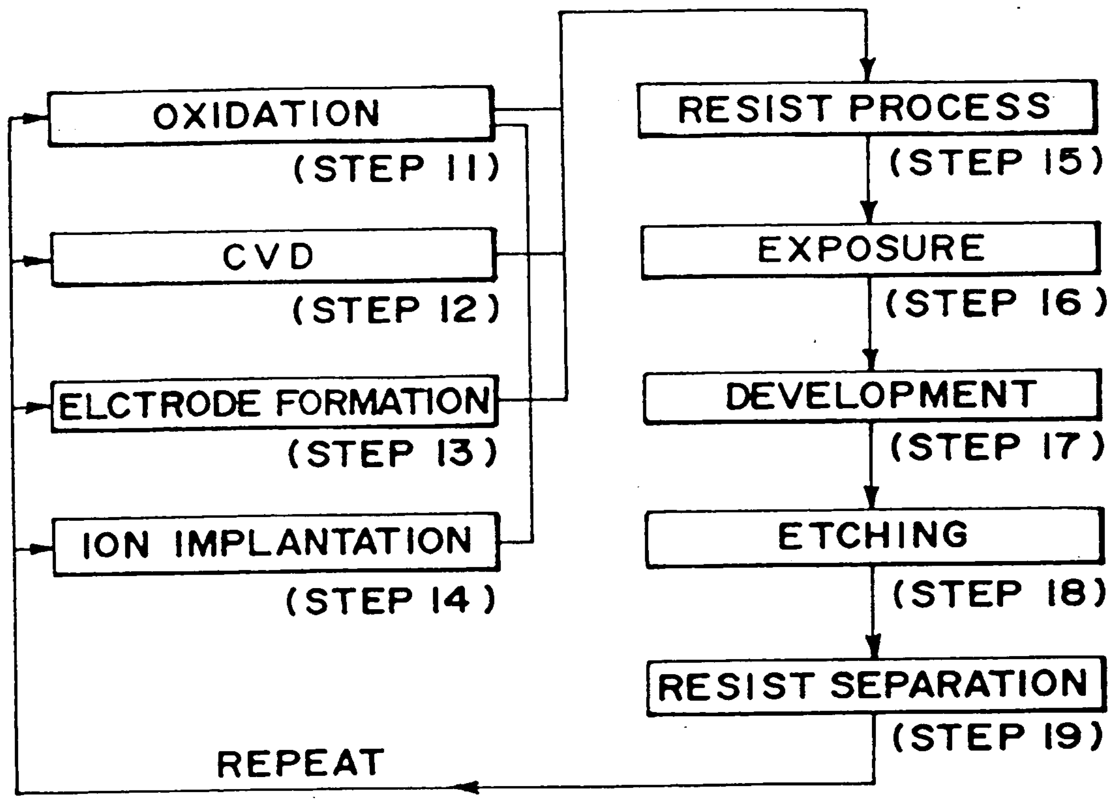
OXIDATION
(STEP 11)
CVD
(STEP 12)
ELCTRODE FORMATION
(STEP 13)
ION IMPLANTATION
(STEP 14)
RESIST PROCESS
(STEP 15)
EXPOSURE
(STEP 16)
DEVELOPMENT
(STEP 17)
ETCHING
(STEP 18)
RESIST SEPARATION
(STEP 19)
REPEAT

FIG. 7